Measuring Clinical Reasoning in Senior Dental Hygiene Students Through the Use of s-OSCEs

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DEDICATION

This thesis is dedicated to my family and friends who never let me give up on my dreams and goals. Their presences served as a constant reminder to continuously work hard toward the plan I set out to accomplish.

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SECTION 1

Introduction

The terms clinical reasoning and critical thinking are frequently used interchangeably, however, they are not the same (1). Critical thinking is the process of intentional higher level thinking to define a patient's problem, examine evidence-based practice in caring for the patient, and make choices in the delivery of care (1–3). Students make the connection between their course content and the ability to provide comprehensive patient care with critical thinking (1–3). Clinical reasoning is the cognitive process that uses thinking strategies to gather and analyze client information, evaluate the relevance of the information, and decide on possible dental hygiene actions to improve the client's physiological and psychosocial outcomes (1–3). Clinical reasoning also involves assessing, assimilating, retrieving, and/or discarding components of information that affect the dental hygiene process of care (1–3). Clinical reasoning requires the integration of critical thinking in the identification of the most appropriate interventions that will improve the client's condition, through analyzing and evaluating an issue to form a judgement (1–3).

It has been determined through various organizations, including the Commission on Dental Accreditation (CODA), the American Dental Education Association (ADEA), and the American Dental Hygiene Association (ADHA) that the acquisition of clinical reasoning skills by dental hygiene students is an essential learning outcome of dental hygiene curricula (4–6). Clinical reasoning is required throughout the dental hygiene process of care as a clinician needs to observe, collect, process, decide, plan, act, evaluate and reflect (7). Students' clinical reasoning is expected to progress as they advance

through the curriculum, as the development of clinical reasoning ensures the best care possible for patients (2,4–6). Clinical reasoning and critical thinking are necessary skills for dental hygiene students to complete the dental hygiene process of care during any clinical encounter (1–3,8).

The dental hygiene process of care involves medical and dental history taking, an assessment of the oral cavity, formulating a dental hygiene diagnosis, implementing therapeutic and preventive care plans and evaluating health outcomes (4–7). A dental hygiene student first uses critical thinking skills through cognitive knowledge centered on scientific evidence in dental hygiene (1–3,8). Clinical reasoning involves processing this knowledge to determine which evidence applies to the clinical encounter (1–3,8). Through clinical reasoning, the dental hygiene student assesses and draws conclusions to properly manage a clinical situation (1–3,8). Clinical reasoning is not an easy skill to measure, as this is a process that occurs in the student's mind (1–3,8). Health care education is continuously examining objective and accurate clinical reasoning testing methods to ensure clinical reasoning progression is occurring (9–11). Currently, health care education is incorporating concept-based curriculum into education as this promotes active learning which in turn improves clinical reasoning. Concept-based curriculum includes problem-based learning (PBL), case-based learning (CBL), flipped classrooms, reflection, and simulation (9–11). Research supports the promotion of active learning and clinical reasoning through concept-based curriculums in health care educations (12–31). Though, dental hygiene literature containing empirical evidence to support clinical reasoning progression is lacking (4,6,32,33).

Purpose of the Study

The purpose of this study is to determine if senior baccalaureate dental hygiene students' clinical reasoning skills improve over the course of their senior year as measured by a summative objective structured clinical examination (s-OSCE).

Statement of the Problem

Clinical reasoning encompasses the qualities future dental hygienists' will need and include, the ability to form hypotheses, collect and analyze pertinent information, provide succinct rationale for their decisions, and solve problems that arise during patient care. Patient care is a dynamic process and clinicians move back and forth through these steps before reaching a decision and taking action (1). However, dental hygiene curricula often evaluate students' competence in each step in isolation. Observing and assessing students in the process of clinical reasoning is challenging and few objective metrics exist. Development of clinical reasoning is the goal for health professional curricula. Programs need to investigate if their curricula is developing this skill in students (4–6,12–33).

Significance of the Study

Dental hygiene curricula must ensure that their graduating dental hygienists are capable of problem-solving independently in order to provide optimal care to patients (4–6). An effective method to measure students' abilities to transfer basic biomedical and clinical knowledge within health professional curricula has not been identified (4–6,12–

33). Yet, CODA states problem solving skills must be assessed throughout dental hygiene students' education to determine competence prior to graduating (4–6). For this reason, it is paramount that more research be completed in the area of evaluating the development of dental hygienists' clinical reasoning skills.

An OSCE is a common form of clinical reasoning assessment that has been used in many areas of health care education including nursing, medicine, and dentistry (5,13,19,21–23,30). OSCEs test all areas of students' capabilities including communication, intellectual and conceptual skills, and professional demeanor in interacting with a standardized patient. OSCEs may be both formative and summative (34). A formative OSCE evaluates students' knowledge on a specific skill while a summative OSCE evaluates comprehensive clinical skills and application of knowledge during one assessment (34). Three summative-OSCEs, each comprised of a patient case, radiographs, and intra-oral photographs were developed to examine whether students' clinical reasoning skills improved over the course of their senior year in a baccalaureate dental hygiene curriculum. This study's findings provide data on the development of clinical reasoning among dental hygiene students and may be used to inform dental hygiene curricular development.

Research Question

What is the progression of baccalaureate dental hygiene students' clinical reasoning skills with regard to the provision of dental hygiene care as measured by a s-OSCE?

SECTION 2

Theoretical Framework

Clinical reasoning is a nonlinear process whereby clinicians follow a process to synthesize and analyze information provided by a patient and an oral assessment throughout the dental hygiene process of care (1). The University of Newcastle developed a clinical reasoning conceptual framework for nursing education (1,7). The University of Newcastle's framework describes the process of making a clinical decision using the following steps: look, collect, process, decide, plan, act, evaluate, and reflect (1). The steps defined in the clinical reasoning processes align with the dental hygiene process of care: assessment, dental hygiene diagnosis, planning, implementation, evaluation, and documentation, and therefore was used as the dental hygiene clinical reasoning framework for this study (Table 1) (7). These components are interrelated and depend on each other to meet the personalized needs of a patient. Through the use of the dental hygiene process, a dental hygienist may be able to reduce, prevent or eliminate contributing factors of a situation (7). Application of the conceptual framework for clinical reasoning to support the dental hygiene care process has yet to be done. It is unknown if this clinical reasoning framework is successful in evaluating the progression of clinical reasoning. The Division of Dental Hygiene at the University of Minnesota developed three separate s-OSCEs using a grading rubric to measure the progression of clinical reasoning that aligns with the dental hygiene process of care and the clinical reasoning conceptual framework (1,7).The clinical reasoning framework begins a sequence evaluating a patient's situation and collecting information (1,7). From there, a

dental hygiene student is to process this information and identify the problem (1,7). As this is completed, the student needs to determine and complete the desired outcome (1,7).

Review of the Related Literature

A literature search was undertaken to determine current practices regarding the assessment of clinical reasoning in the health professions. The review of the literature covered a 10-year period, from 2008 to 2018. The search included the use of two electronic bibliographic databases, Ovid Medline and PubMed. Only empirical studies were reviewed. Search phrases included clinical reasoning, nursing, medicine, assessment tools, OSCE, virtual patient, dental hygiene, and dental education. A total of 95 articles were reviewed, of which 50 met the inclusion/exclusion criteria. Studies were included if they were completed within the last 10 years; measured clinical reasoning or critical thinking; included primary data; evaluated health care professionals; and took place at universities. Studies were excluded if they did not collect primary data testing clinical reasoning or critical thinking; completed greater than 10 years prior; and published in a language other than English. Limited studies exist measuring the progression of clinical reasoning in health care students. More studies have been completed measuring the progression of critical thinking. Critical thinking is an important aspect of the clinical reasoning process. Therefore, those studies were included in this literature review.

Clinical Reasoning

The process of clinical reasoning consists of three intellectual progressions including learning, judging, and concluding, completed through the clinical reasoning theoretical framework as shown in Table 1 (2). Intellectual progression uses previously learned skills involving cognitive, behavioral, and mental habits to determine proper clinical reasoning to rationalize a conclusion (2). It is important that health care providers understand the process of clinical reasoning, as it supports evidence-based care (3,4). A clinician with strong clinical reasoning skills will be inclined to ask relevant questions, connect new knowledge to prior knowledge, solve problems, and create and support diagnoses based on evidence (4). Evidence-based care is backed by research proving a particular method as the best treatment plan for the unique characteristics, circumstances, and preferences of a specific patient (1–4). Although evidence-based care is the standard health care providers are held to, it may not be achieved when the thought processes involved in clinical reasoning are lacking (3). Many health care providers produce unfavorable patient outcomes such as improper diagnosis, inaccurate treatment, and inadequate management of complications because completion of the various steps in clinical reasoning are not completed (1–3).

Development of clinical reasoning requires understanding the concepts as described in Table 1 (1). For a novice learner each step must be recognized and understood before moving onto the next (1). This eliminates the risk of assumptions regarding a patient's case and developing an incorrect diagnosis and treatment plan (1). As a clinician becomes more experienced these steps may be combined or steps may be completed out of order before making a decision as described in Figure 1 (1). A nursing

example is used because there are no examples for dental hygienists that exist. It is vital for dental hygiene curricula to adopt The University of Newcastle Clinical Reasoning Framework as this describes perfectly how the dental hygiene process of care is completed (1).

Measurement of clinical reasoning. Health care educators desire to identify the best method in measuring clinical reasoning that is both objective and accurate (9–11). The ideal mechanism will identify clinical reasoning is occurring throughout a students' education, as the development of clinical reasoning occurs over time (4–6,12–33,35). Identifying clinical reasoning progression has become a top priority in health care education (4–6,12–33).

Within the literature, several mechanisms to measure clinical reasoning were found. Educators use standardized testing or their own created exam to measure the progression of clinical reasoning (4,6,18,19,26,32). Two common standardized testing measurement tool produced by the American Philosophical Association are the California Critical Thinking Disposition Inventory (CCTDI) and the California Critical Thinking Skills Test (CCTST) (4,6,18,19,26,32). The CCTDI measures the affective domain of clinical reasoning by assessing student motivation to use clinical reasoning to address problems and make decisions (4,18,19,26,32). The CCTDI score emphasizes truth seeking, open mindedness, inquisitiveness, analyticity, systematicity, critical thinking confidence, and cognitive maturity (4,18,19,26,32). The CCTST is designed to measure student success in problem-solving and decision-making formed by their reasoning

(4,18,19,26,32). The CCTST measures induction, deduction, analysis, inference, and evaluation (4,18,19,26,32). The Health Science Reasoning Test (HSRT) is a subcategory of the CCTST assessing clinical reasoning of health care providers specifically (4,6,32). The HSRT measures discipline-neutral cognitive domains needed for decision-making including analysis, interpretation, inference, evaluation, explanation, deductive reasoning, and inductive reasoning (4,6,32). Each test emphasizes a variety of cognitive domains (4,6,18,19,26,32). Through the use of these standardized tests clinical reasoning progression can be measured (4,6,18,19,26,32).

Another measurement tool of clinical reasoning progression is an objective structured clinical examination (OSCE) (5,13,19,21–23,30). An OSCE will often simulate a real-world clinical situation to assess competence within a safe learning environment (5,13,19,21–23,30). Faculty are able to evaluate students demonstrating clinical behaviors with standardized patients (5,13,19,21–23,30). Typically, isolated clinical skills are evaluated via OSCE stations as students' progress through the curriculum (5,13,19,21–23,30). More recently, summative OSCEs have been used to evaluate metacognition and provide evidence of students' clinical reasoning skills (5,34). One type of summative OSCE is a patient case scenario where an abundance of information is given to the student; the student must decipher what is important and how to make evidence-based decisions to care for the patient (5,34). If errors are made, the examiner can discuss the proper treatment in a comfortable setting so the student can learn and grow from their mistakes (5,34).

Development and assessment of clinical reasoning in health care professions.

Traditional learning. Because of the complex and constantly changing health care system, curricula have become over-crowded decreasing the time available for activities that develop clinical reasoning and critical thinking (9–11). National testing shows that health care students are not retaining all of this knowledge because traditional learning methods, which require memorization versus deep understanding of a topic, are being used (9–11). Traditional learning curricula involve textbooks, slides, and handouts which provides information for student's learning (9–11). This approach puts faculty in the position to deliver extensive amounts of content to sometimes unengaged students (9–11). This type of learning is a linear process (9–11). Similarly, traditional assessment methods are not designed to assess clinical reasoning, rather only assess student's knowledge. Traditional assessment methods ask students to answer a specific question, but do not ask for students to reason their answer (9–11). Traditional assessment is completed through multiple choice, true/false, filling in the blank, and matching exams (9–11). This method of measuring does not allow for problem solving, communication, or clinical reasoning to occur (9–11).

To address this issue, health care education is shifting from traditional learning curricula to concept-based curricula (CBC) including problem-based learning (PBL), case-based learning(CBL), flipped classrooms, reflection and simulation (9–11). Because it is not realistic or feasible to teach all course content in the classroom, health care educators are now using concept-based assessments to evaluate the curriculum and

develop concepts and exemplars (9–11). Concepts organize main principles or main points in the curriculum content and exemplars represent necessary clinical understanding applied to the related concept (9–11). Knowledge needs to be structured around main concepts which facilitates understanding and application of knowledge to other circumstances (9–11). Obtaining a vast knowledge base requires students to be exposed to multiple exemplars of a certain concept (9–11). Through conceptual teaching students are expected to use learned concepts and transfer those concepts to new situations promoting clinical reasoning (9–11). This format of learning is student-oriented fostering the development of clinical reasoning (9–11). Class time no longer revolves around the instructor lecturing, but rather filled with problem-solving activities and guided learning using questions that bring students as close as possible to actual clinical experiences (9–11).

Problem-based learning and case-based learning. Problem-based learning and case-based learning employs real-life patient experiences to create a learning environment that includes active learning, clinical reasoning, and critical thinking (1,12,13,24,25,27,36). Instead of students passively learning through retaining facts, students are now actively engaged in the patient case (12,13,24,25,27,36). Instructors select appropriate patient cases based on the main concepts selected in the curriculum content (12,13,24,25,27,36). The objective of PBL and CBL is to show students the importance of the learned concept by giving an example in an appropriate and accurate context (12,13,24,25,27,36). The idea behind PBL and CBL is that learning occurs when a clinical problem is associated with it (12,13,24,25,27,36). Also, promotion of a broaden

knowledge base, effective student collaboration, and improved intrinsic, self-directed clinical reasoning skills occurs with the use of PBL and CBL (12,13,24,25,27,36). The layout of the patient case should mimic a real patient encounter allowing the students to ask pertinent questions and have full access to the patient's chart (12,13,24,25,27,36). This promotes purposeful knowledge construction and the generation of an efficient methodology to clinical reasoning (12,13,24,25,27,36). Learning occurs as students work through the clinical reasoning process through student discussions and hypotheses of clinical assessment, treatment plan, and diagnosis (12,13,24,25,27,36). Students must correlate their previous knowledge and experiences in order to come to a conclusion (12,13,24,25,27,36). Students are challenged when validating and elaborating their hypothesis (12,13,24,25,27,36). During this explanation, students may discover knowledge gaps which require further research or possibly a new hypothesis (12,13,24,25,27,36). Instructors are responsible to guide students to their conclusion through promoting questions for students to think critically to discover their answer (12,13,24,25,27,36).

Callis et al., Al-Madi, Whitney et al., Pardamean, Kelly et al., and Shigli et al. measured clinical reasoning progression in dental students with the use of PBL and CBL curriculums in comparison to traditional curriculums (12,13,24–27). Their study samples consisted of either experimental and control groups comparing multiple dental institutions or multiple cohorts within the same dental institution (12,13,24–27). Testing methods consisted of pre and post-tests using CCTDI, CCTST, HSRT, OSCEs, and multiple choice exams (12,13,24–27). Al-Madi et al. and Shigli et al. found statistically

significant differences between the pre and post-test in both PBL and CBL curriculums (12,24). Al-Madi et al. found that the dental students had a statistically significant decrease in knowledge on the traditional curriculum questions compared to PBL when the dental students were retested (24). Similarly, Shigli et al. found similar results that clinical reasoning knowledge retention is greater in CBL curriculums versus traditional curriculums (12). This finding may indicate that PBL and CBL curriculums have a greater long-term retention than traditional curriculum (24). However, Callis et al., Whitney et al., Pardamean, Kelly et al. found no continuous, significant improvements among the cohorts tested in PBL and CBL curriculums compared to traditional curriculums between the pre and post-test (13,25–27).

Flipped classroom. The flipped classroom teaching model is a student-oriented teaching strategy to develop active learning (28–31,37–41). The roles of students and instructors have changed in this model (28–31,37–41). Instructors are mentors and guide an interactive classroom through questions (28–31,37–41). Students learn from one another through collaborative learning activities (28–31,37–41). The goals of a flipped classroom are to activate and deepen students' clinical reasoning abilities and have both students and instructors be engaged (28–31,37–41). The time students previously dedicated to homework or projects outside of class is now used for viewing lecture (28–31,37–41). Class time is devoted to active learning through case studies, discussions, and problem solving that broadens the understanding of the main concepts addressed in the curriculum (28–31,37–41). Students are first introduced to the lecture material via readings, slides, voice-over lectures, or prerecorded videos (28–31,37–41). Students

come to class prepared with foundational knowledge on the lecture concepts (28–31,37–41). The instructors are easily accessible to students to answer questions in regards to application of the new concepts (28–31,37–41). Instructors have the ability to emphasize the more important concepts in class, but still deliver significant information through didactic lectures outside of class time (28–31,37–41).

Xiao et al. and Chutinan et al. introduced a flipped classroom to dental students to measure critical thinking with the use of content-based quiz questions (28,29). Both studies evaluated two consecutive cohorts of dental students (28,29). Xiao et al. found statistically significant results showing a flipped classroom improved critical thinking (28). However, Chutinan et al. found the results were not statistically significant (29). Tune et al. and Gillispie assessed clinical reasoning progression in medical students with the implementation of a flipped classroom approach (30,31). Both studies found that clinical reasoning progressed with the flipped classroom method (30,31). However, while Tune et al. found that clinical reasoning progression could be measured effectively by a multiple choice exam, Gillispie compared two testing methods, multiple choice exam and an OSCE, found that clinical reasoning progression could not be effectively measured by a multiple choice exam, but was effectively measured by an OSCE (30,31). Jensen et al. suggest that the process and interaction of students using active learning is what encourages student learning and not the specific method of a flipped classroom (40).

Reflection. Another form of concept-based teaching is reflection (14–17). No studies exist that measure progression of clinical reasoning with reflection, but there are

studies evaluating critical thinking progression (14–17). Reflective writing is a strategy for enabling students' reasoning skills by offering students a moment to review their decision-making process (14–17). Writing inspires individuality and organizational, descriptive, and observational skills (14–17). Students can evaluate what was done correctly and identify areas needing improvements (14–17). Reflection encompasses focused thinking on thoughts, actions, and experiences associated with the clinical encounter (14–17). Students are reflecting on both their judgments during and after the encounter developing a profound understanding of their thoughts and actions resulting in enhanced critical thinking (14–17). Instructors facilitate strong reflective skills by understanding their students dilemmas and providing constructive feedback (14–17). Instructors must be actively involved in providing effective feedback in order for students to learn from their mistakes (16). Instructors may identify common themes among students where the class is struggling and discussions among the class may arise to find solutions (14–17)

Sahoo et al., Carter et al., Zhang et al., and Mun all found improvements in medical and nursing students critical thinking abilities with the use of written reflections (14–17). Carter et al. and Zhang et al. used standardized testing similar to CCTDI to measure critical thinking progression in nursing students with the incorporation of written reflections in nursing students (15,16). Their study populations included multiple cohorts from the same institution and experimental and control groups. Sahoo et al., Carter et al., Zhang et al., and Mun found a common theme regarding the importance of constructive

feedback from instructions in student reflections. However, Zhang et al. was the only study to find statistically significant results (16).

Simulation. Patient simulation is used in health care curricula with the idea that when a student is exposed to a simulated patient encounter, a student will be able to recognize and effectively manage a similar real-life encounter (18–23). Simulation is the re-enactment of a clinical scenario to help students learn the cognitive and/or psychomotor skills required to perform necessary skills (18–23). Students can freely make mistakes, learn from them, and become confident in their abilities in a controlled environment during simulation (18–23). Students learn interviewing skills, medical-history taking, care implementation, treatment planning, and documentation (18–23). Simulation can be live, virtual, role-playing or used with mannequins (18–23). Repeated, deliberate exposure can be created to allow students to perceive, practice, and progress their clinical reasoning (18–23). Instructors can manipulate the simulation experience to include both common encounters or rarely seen complications in health care (18–23).

Several studies have evaluated the progression of critical thinking when patient simulation is incorporated into dental, medical, and nursing curriculum (18–23). Their studies used experimental and control groups using a pre and post-test measured by CCTDI, CCTST, and an OSCE (18–23). Zarifsanaiey et al., Weiner et al., Fida et al. Isaza-Restrepo et al. found statistically significant results in dental, medical, and nursing students' clinical reasoning with the incorporation of patient simulation as measured by

their respective testing methods (19–21,23). Conversely, Ravert and Oliven et al. did not find statistically significant results in medical and nursing students (18,22).

Assessment of clinical reasoning in dental hygiene. A review of the literature suggests that progress testing, reflection, and simulation may promote learning and potentially enhance clinical reasoning (4–6,32,33). However, few research studies have been conducted to evaluate the impact of concept-based curricula in dental hygiene students' clinical reasoning abilities.

Problem-based learning and case-based learning. Ali et al. used progress testing in dental therapy and dental hygiene students to measure critical thinking progression through a bank of multiple choice questions (33). Progression testing consisted of testing the same cohort of students from their first, second, and third years of dental therapy/hygiene school (33). The multiple-choice exam consisted of a bank of questions that were randomly assigned to students. (33). Ali et al. found improvements in students from the first to second year, but not from the second to third year (33). The improvements were slight, but did show that using progress testing can measure critical thinking and determine students' knowledge (33). Partido evaluated critical thinking progression between both third and fourth year dental hygiene students as measured by CCTDI and HSRT (32). Partido found that fourth year students had statistically significant critical thinking progression indicating that the curriculum was successfully teaching clinical reasoning skills (32). McComas et al. created a patient case to evaluate dental hygiene students' critical thinking as measured by a modified OSCE (m-OSCE)

(5). A m-OSCE combines multiple choice questions with rotating testing stations allowing for evaluation of factual context and skill competence (5). Three of the testing stations asked 24 multiple choice questions, one station asked a fill in the blank question, and one station asked the students to write a treatment plan (5). McCommas et al. did not find critical thinking progression and found that multiple choice questions can't reliably measure critical thinking (5). However, faculty identified gaps in the curriculum based on the multiple choice results (5).

Reflection. Wetmore et al. assessed the progression of critical thinking using reflective blogs in dental hygiene curriculum, as measured by HSRT (6). The experimental study was conducted comparing student-written reflective blogs used at one dental institution to a control group at another institution that did not use reflective blogs (6). An HSRT pre-test was given prior to the introduction of reflective blogs to both the experimental and control group (6). Both groups completed a post-test HSRT following the completion of the study (6). Results showed that both the experimental and control group had increased critical thinking skills indicating that the curriculum was indeed teaching critical thinking and that reflective writing didn't improve critical thinking skills in the experimental group (6).

Simulation. Allaire wanted to determine the affect virtual patient simulation had on critical thinking in dental hygiene students (4). The progression of critical thinking was measured with a pre and post-test standardized test, HSRT (4). Allaire found that

virtual patient simulation does not influences critical thinking abilities (4). No other studies were found using simulation in dental hygiene.

Over the years, dental education has modified their curricula and teaching methods to include problem-solving skills, case-based learning, and simulation to prepare competent clinicians (4–7,20,26,27,32,33). Current literature supports the idea that concept-based learning contributes to students' critical thinking, clinical reasoning, and assurance in making evidence-based decisions (4–6,32,33). However, results are still inconclusive on the effectiveness of these methods because of the limited literature available to support clinical reasoning progression in dental hygiene students (4–6,32,33). It is evident that additional studies are needed to determine if students' clinical reasoning skills are developing during the curriculum (4–6,32,33). Further research is necessary to evaluate the effectiveness of concept-based strategies intended to promote progression of students' clinical reasoning skills (4–6,32,33). Long-term studies, larger sample sizes, and the use of experimental and control groups among multiple dental hygiene institutions would aid in generalizability of the research (4–6,32,33).

Therefore, the purpose of this study is to determine if senior baccalaureate dental hygiene students' clinical reasoning skills improve over the course of their senior year as measured by a s-OSCE.

SECTION 3

SYNOPSIS

Purpose/Objective: Dental hygiene students must be learning, using, and understanding clinical reasoning to complete the dental hygiene process of care during any clinical encounter. It is expected that students' clinical reasoning skills will progress as they advance through the curriculum. The study findings will provide data to show whether clinical reasoning progresses throughout the curriculum.

Methods: This study employed a cohort/repeated measures design to measure change in baccalaureate dental hygiene students' clinical reasoning skills with regard to the dental hygiene process of care over the course of one year (n=26). A practice case was given to students one week prior to testing. Students were tested three times over their senior year in the fall semester, spring semester, and summer semester. Analyses included descriptive statistics and a repeated measures ANOVA model test.

Results: All criterions measured on the s-OSCE rubric showed improvement from the fall to spring semester, but scores declined from the spring to summer semester. However, scores were higher in summer than fall. The assessment criterion was the only area students had a statistically significant positive increase in clinical reasoning scores. The evaluation criterion showed student scores improving over the course of the year. However, those results were not statistically significant.

Conclusion: Clinical reasoning progression was not found as measured by the s-OSCE. The results found in this study were consistent with the research findings that students have not shown clinical reasoning progression over a specific time period chosen by the investigators.

Keywords: dental hygiene, curriculum, students, clinical reasoning

MANUSCRIPT

This manuscript will be submitted to the *Journal of Dental Education (JDE)*.

Clinical reasoning is the cognitive process that uses thinking strategies to gather and analyze client information, evaluate the relevance of the information, and decide on possible dental hygiene actions to improve the client's physiological and psychosocial outcomes (1–3). Clinical reasoning requires the integration of critical thinking in the identification of the most appropriate interventions that will improve the client's condition, through analyzing and evaluating an issue to form a judgement (1–3).

It has been determined through various organizations, including the Commission on Dental Accreditation (CODA), the American Dental Education Association (ADEA), and the American Dental Hygiene Association (ADHA) that the acquisition of clinical reasoning skills by dental hygiene students is an essential outcome of dental hygiene curriculum (4–6). It is expected that students' clinical reasoning skills progress as they advance through the curriculum (4–6). Dental hygiene students must be learning, using, and understanding clinical reasoning to perform the best care possible for patients (2,4–6). Critical thinking and clinical reasoning are necessary skills for dental hygiene students to complete the dental hygiene process of care during any clinical encounter (1–3,8).

Clinical reasoning is required throughout the dental hygiene process of care as a clinician needs to observe, collect, process, decide, plan, act, evaluate and reflect (7). The dental hygiene process of care involves medical and dental history taking, an assessment of the oral cavity, formulating a dental hygiene diagnosis, implementing

therapeutic and preventive care plans and evaluating health outcomes (4–7). Through clinical reasoning, the dental hygiene student assesses and draws conclusions throughout the process of care properly treat the clinical situation using evidence-based care (1–3,8).

Because of the complex and constantly changing health care system, an overabundance of curriculum content is now given to students often through traditional learning methods which include textbooks, slides, and handouts (9–11). Traditional assessment methods are not designed to assess clinical reasoning, rather only assess students' knowledge. Traditional assessment methods include multiple choice, true/false, filling in the blank, and matching exams (9–11). This method of measuring does not require problem solving, communication, or clinical reasoning to occur (9–11).

Health care education is shifting from traditional learning curricula to concept-based curricula (CBC) including problem-based learning (PBL), case-based learning(CBL), flipped classrooms, reflection and simulation (9–11). It is not realistic or feasible to teach all course content. As a result, health care educators are now using concept-based assessments to evaluate the curriculum and develop concepts and exemplars (9–11). Concepts organize main principles or main points in the curriculum content and exemplars represent necessary clinical understanding applied to the related concept (9–11). Knowledge needs to be structured around main concepts which facilitates understanding and application of knowledge to other circumstances (9–11). Obtaining a vast knowledge base requires students to be exposed to multiple exemplars of a certain concept (9–11). Through conceptual teaching students are expected to use

learned concepts and transfer those concepts to new situations promoting clinical reasoning (9–11). This format of learning is student-oriented fostering the development of clinical reasoning (9–11).

Research shows concept-based curricula improves health care student learning by promoting active learning and facilitating clinical reasoning (12–31). Students are able to examine, problem solve, and reflect case studies which lead to improved critical thinking, clinical reasoning, and communication skills in health care student (12–31). Learning by doing and repeated practice allows students to understand each case problem (12–31).

Few research studies have been conducted to evaluate the impact of concept-based curricula in dental hygiene students' clinical reasoning abilities. A review of the literature suggests that progress testing, reflection, and simulation may promote learning and potentially enhance clinical reasoning (4–6,32,33). Current literature supports the idea that concept-based learning contributes to students' critical thinking, clinical reasoning, and assurance in making evidence-based decisions (4–6,32,33). However, results are still inconclusive on the effectiveness of these methods because of the limited literature available to support clinical reasoning progression in dental hygiene students (4–6,32,33). It is evident that additional studies are needed to determine if students' clinical reasoning skills are developing during the curriculum (4–6,32,33). Further research is necessary to evaluate the effectiveness of concept-based strategies intended to promote progression of students' clinical reasoning skills (4–6,32,33). Long-term studies, larger sample sizes, and the use of experimental and control groups

among multiple dental hygiene institutions would aid in generalizability of the research (4–6,32,33).

The primary purpose of this study is to determine if senior baccalaureate dental hygiene students' clinical reasoning skills improve over the course of their senior year as measured by a summative-OSCE (s-OSCE). This study's findings provided data on the development of clinical reasoning among dental hygiene students and inform dental hygiene curricular development.

Methods and Materials

This study employed a cohort/repeated measures design to measure change in baccalaureate dental hygiene students' clinical reasoning skills with regard to the dental hygiene process of care over the course of one year.

A convenience sample of 26 senior baccalaureate dental hygiene students enrolled at the University of Minnesota was used for the study. In order to maintain anonymity, students were randomly numbered one through twenty-six. The PI was not blinded to who the students were. To be included in the study, students had to be 18 years and older, enrolled as a baccalaureate dental hygiene student at the University of Minnesota, read and understand the English language, and in good academic standing. The study took place during the 2017-2018 academic year. Ethical approval was given by the Institutional Review Board (IRB) at the University of Minnesota prior to any interaction with subjects. IRB approval STUDY00003310.

A s-OSCE was developed to assess change in students' clinical reasoning skills. The PI modified the existing previously developed s-OSCE. The s-OSCE is a graded

component of a required clinical course in the dental hygiene curriculum, administered at the end of each semester of the senior year in the biomedical library at the University of Minnesota. The principal investigator (PI) proctored each exam. Each semester, the PI and the dental hygiene clinic coordinator calibrated s-OSCE grading to ensure consistent grading practices and inter-rater reliability. Student study materials were released to the students one week before the exam. Materials included a practice case, which was an exact replica of the s-OSCE format containing an individualized patient case scenario and rationale answer sheet. Each case scenario throughout the study was different.

Instrument: Health Partners Institute, a nonprofit health care provider and health insurance company providing care, coverage, research and education first developed the case study for their personal dental research and education using the website, DDSim (42,43). A s-OSCE was previously developed to coincide with the case study by a University of Minnesota dental hygiene faculty member and a graduate student for the pilot study of the clinical reasoning s-OSCE. A total of four exams were used in this research study; a practice case and three exams were administered over each semester of the senior year. Two dental hygiene faculty members and the graduate student calibrated to create an answer key for each exam. The s-OSCE was piloted in the summer of 2017 to the senior class. After the pilot, test questions were modified by the PI and re-worded for better understanding. Although questions were modified, the answer to each question stayed the same. Each s-OSCE case scenario was different, with the second and third s-OSCEs designed to test at a higher cognitive level in order

to ascertain the development of students' clinical reasoning skills. Patients in each case scenario were different genders, ages, races, dental concerns and medical conditions. However, each s-OSCE contained the same questions.

Each s-OSCE contained 22 questions, which consisted of 16 open-ended questions and six multiple choice questions. Students were given one hour and five minutes to complete each s-OSCE. The 22 questions aligned with the dental hygiene process of care; eight questions pertained to assessment of oral and general health, eight questions to treatment planning, and six questions to dental hygiene diagnosis. Implementation and documentation were not evaluated on the s-OSCE because of the test format.

The s-OSCE was designed to mimic a patient appointment. The first questions evaluated chief complaint; medical and dental history; head and neck exam; periodontal concerns; radiographs; and caries experienced. These questions were open-ended and required the student to compare findings from the previous visit to new findings and how it impacts treatment. The next set of questions comprised a multiple-choice question followed by an open-ended question requiring students to provide rationale to support the multiple-choice response. These questions were based on caries management by risk assessment (CAMBRA) and the periodontal risk assessment (PRA) used at the School of Dentistry and were aimed to assess the patient's oral health status regarding both caries risk and periodontal disease and evaluate students' ability to provide a dental hygiene diagnosis. The next set of questions assessed treatment

planning, self-care, consultations, and recall interval. The s-OSCE did not address care implementation.

For each question, one point was given for the correct answer(s) and one point was given for the correct rationale(s). Most questions had multiple correct responses considering the patient characteristics in the case. For example, in one case the patient was classified as high caries risk. The student earned one point for correctly identifying that the patient was at high caries risk. Then, the student needed to think about the factors contributing to the high caries risk and explain modifications that could be made. Modifications could include treatment options such as a prescription fluoride toothpaste or dietary counseling. This was the clinical reasoning aspect of the exam. Students would receive one point for every appropriate modification given for each case. Clinical reasoning was assessed by the rationale given by the student. Partial points were awarded for incomplete answers.

Additionally, a rubric was used to measure clinical reasoning occurring through each patient case. There were five rubric criteria including assessment, dental hygiene diagnosis, treatment planning, evaluation and clinical reasoning. Each successive s-OSCE had a different patient case and different number of possible correct answers for each question. The rubric assessed the quality of the students' answers related to each criterion. The rubric rating scale included three levels with scores of 1, 2, or 3. Three points were awarded if the student consistently answered the specific criterion correctly which meant that the student answered the question correctly at least 85% of the time. Two points were awarded if the student answered the specific criterion correctly 50-

84% of the time. One point was awarded if the student answered the specific criterion 0-49% of the time. This rubric can be found in Appendix C.

Statistical analysis: A repeated measures ANOVA model (i.e. linear mixed effect model with a random student effect) was completed evaluating the mean scores as a whole of each of the three s-OSCE exam dates and comparing scores achieved in three of the dental hygiene process of care components: assessment, diagnosis, and treatment planning. P-values less than 0.05 were considered statistically significant. SAS V9.3 (SAS Institute Inc., Cary, NC) was used for the analysis.

Descriptive statistics were calculated for the test scores. A repeated measures ANOVA model (i.e. linear mixed effect model with a random student effect) was used to compare the mean total scores between the fall, spring, and summer semesters. The individual test component scores are on an ordinal scale with a small range, so Friedman's tests (a non-parametric alternative to repeated measures ANOVA) were used. If the overall ANOVA was significant, pairwise comparisons were made with a Tukey adjustment for multiple comparisons. P-values less than 0.05 were considered statistically significant. SAS V9.3 (SAS Institute Inc., Cary, NC) was used for the analysis.

Pairwise comparisons were calculated for assessment, treatment planning, clinical reasoning, and total score. Pairwise comparisons were not completed for dental hygiene diagnosis and evaluation, which were not significantly different.

Results

The senior dental hygiene class at the University of Minnesota consisted of 27 students. One student didn't attend one of the scheduled s-OSCE date. Because of this, that score was eliminated from the study. A total of 26 student s-OSCE scores were evaluated in this study.

Table 2 describes the mean, standard deviation, median, minimum and maximum scores achieved by the students as a class. The dental hygiene process of care individual components are reported as whole class scores on the clinical reasoning grading rubric. Each component is assessed through the rubric scoring as one, two, or three. The total score is the sum of all of the components on the clinical reasoning grading rubric.

In the mean total score component, spring and summer clinical reasoning scores were statistically significantly higher than fall. However, between spring and summer, there was no statistically significant difference in clinical reasoning scores. Fall 2017 (6.0) vs Spring 2018 (7.8) $p<.0001$, Fall 2017 (6.0) vs Summer 2018 (7.4) $p=0.0011$, Spring 2018 (7.8) vs Summer 2018 (7.4) $p=0.6095$.

In the assessment component, a change in clinical reasoning with regard to students' assessment ability consistently improved and were statistically significant throughout the study. Fall 2017 (1.2) vs Spring 2018 (1.6) $p=0.0104$, Fall 2017 (1.2) vs Summer 2018 (1.9) $p<.0001$, Spring 2018 (1.6) vs Summer 2018 (1.9) $p=0.0251$.

In treatment planning, changes in treatment planning scores were statistically significant from fall to spring showing improved scores. However, Spring vs Summer showed a statistically significant decline in student clinical reasoning in treatment

planning scores. Fall 2017 (1.0) vs Spring 2018 (1.7) p<.0001, Fall 2017 (1.0) vs Summer 2018 (1.3) p=0.0762, Spring 2018 (1.7) vs Summer 2018 (1.3) p=0.0015.

In clinical reasoning, changes in clinical reasoning scores were statistically significant from fall to spring. However, spring vs summer showed a statistically significant decline in student clinical reasoning scores. Fall 2017 (1.0) vs Spring 2018 (1.3) p=0.0007, Fall 2017 (1.0) vs Summer 2018 (1.1) p=0.6543, Spring 2018 (1.3) vs Summer 2018 (1.1) p=0.0091.

Table 3 provides data on the assessment component of the s-OSCE. Based on the grading rubric that was scored one through three, three being the highest achievable score, students scored a one or two on all three s-OSCEs; fall, spring, and summer. Slight improvement in students' assessment scores are evident as students earned more twos on the grading rubric as they progressed through their senior year. Table 2 shows clinical reasoning scores in the assessment component improved at a level of statistical significance.

Table 4 explains data on the dental hygiene diagnosis component of the s-OSCE. Although senior dental hygiene students showed improvement in dental hygiene diagnosis from fall to summer, there was a decline in scores from spring to summer as measured through the use of the s-OSCE. Table 2 shows clinical reasoning scores in the dental hygiene diagnosis component not statistically significant.

Table 5 describes data on the treatment planning component of the s-OSCE. Based on the grading rubric, students scored a one or a two on all three s-OSCEs. From the fall s-OSCE to the spring, improvements were made as more students scored a two

on the grading rubric. However, from the spring s-OSCE to the summer, student scores declined and more ones were earned on the grading rubric. Although senior dental hygiene students showed improvement in treatment planning from fall to summer, there was a decline in scores from spring to summer as measured through the use of the s-OSCE. Table 2 shows clinical reasoning scores in the treatment planning component having statistically significant negative change.

Table 6 displays data on the evaluation component of the s-OSCE. Based on the grading rubric, students scored a one or a two on all three s-OSCEs. Improvement was shown from fall to summer. Senior dental hygiene students showed continuous improvement in scores in evaluation as measured through a s-OSCE, but the improvement was not statistically significant according to the ANOVA test. Table 2 shows clinical reasoning scores in the evaluation component not statistically significant.

Table 7 outlines data on the clinical reasoning component of the s-OSCE. Based on the grading rubric, students scored a one or a two on all three s-OSCEs. During the spring s-OSCE, a few students increased their clinical reasoning score, but declined again during the summer s-OSCE. Although senior dental hygiene students showed improvement in clinical reasoning from fall to summer, there was a decline in scores from spring to summer as measured through the use of the s-OSCE. Table 2 shows a statistically significant negative change in the clinical reasoning scores from spring to summer. Scores from fall to summer were not statistically significant.

Discussion

The purpose of this study was to assess senior dental hygiene students' progression of clinical reasoning throughout their senior year measured by a s-OSCE. The s-OSCE tested a concept-based assessment method was used rather than traditional assessment methods such as multiple choice, true/false, filling in the blank, and matching exams (44,45).

Students' clinical reasoning progression was evaluated using the same standard questions each semester of testing. As the curriculum progressed, each s-OSCE case study became more challenging to the students. Using this style of testing allowed for each s-OSCE to measure students' knowledge gained through classroom curriculum and clinical experience as well as assess the development of clinical reasoning skills.

A notable improvement during the study was made from fall to spring in student scores in the dental hygiene process of care components. Specifically, the components assessment and evaluation consistently improved throughout the duration of the study. Dental hygiene diagnosis, treatment planning, and clinical reasoning student scores were stagnant or declined from spring to summer. These results provide a gap in the curriculum allowing faculty to evaluate areas of potential improvement. The component of clinical reasoning did not improve as expected. Students gave the correct answer to the question, but they didn't give rationale or reasoning behind how their answer would affect the patient's treatment. This may point out that there is a gap in the curriculum and that students may need to provide better guidance in how to provide rationale. It is unknown whether students misinterpreted the question and didn't realize there was a reasoning portion of each question or if they chose not to answer because they didn't

know how it would affect treatment. Perhaps, students were unable to provide rationale; this may need to be emphasized in the curriculum. Giving students the option to not answer because they don't understand the question allows educators to see where the curriculum is lacking and eliminates students guessing on questions (33). The curriculum needs to identify where this is lacking. Potentially, a course(s) is lacking the clinical reasoning component.

Students understood the s-OSCE accounted for ten percent of their final course grade. Reed et al. and White et al. found that grades do not always motivate students to learn (46,47). When grades are the emphasis, students resort to memorization (46,47). Also, students may not be self-motivated to do their best (46,47). Some students are not concerned with their final course grade or their GPA, especially if they are not specializing after their undergraduate educational career (46,47). The PI perceived that the students weren't focused. Although there was a practice exam available as a tool for students to prepare for the first exam, many students did not use it. Following the first and second s-OSCE, the PI explained the test answers in a recorded video, but it appeared that many didn't watch the recording. The third and final s-OSCE was given in the last semester of their senior year. Students may have lost motivation to do well on the s-OSCE because of other academic requirements facing them at that time.

Dental hygiene curricula places an emphasis on clinical reasoning (4,5). Generally, grading practices are intensified when a project or assignment is important to students' learning. Currently, there isn't a set passing score on the s-OSCE. A potential future s-OSCE grading strategy could be to structure grading similar to the National

Board Dental Hygiene Examination (NBDHE) that all dental hygienists must pass to become licensed which is set at seventy-five percent or the exam needs to be retaken (48). The s-OSCE would need to be retaken if the student obtains a score less than seventy-five percent correlating with NBDHE grading practices. Not only does this show the importance of clinical reasoning, but also encourages students to be better prepared as the s-OSCE plays a role in students' final course grade. The s-OSCE could one day replace the clinical patient-based board exam as this exam can be modified to include all aspects of the dental hygiene process of care. Instrumentation could be assessed through mannequins and typodonts

Personalized debriefing could have been beneficial to students. Students were given generalized feedback through access to a recorded video of the previous s-OSCE. Students were not given individual feedback following each s-OSCE following their performance. Clinical reasoning may not purely occur by chance (49,50). Interventions, such as debriefing, allow students to reflect on their performance and allow faculty to give performance feedback (49,50). When debriefing occurs, students have performed better on their assessments (49,50).

Limitations of this study include results not generalizable to students in other programs due to a small sample size at one university. A control group would have strengthened the study design. All students enrolled in this class must take the s-OSCE because it is a part of the UMN curriculum. However, we could have included another dental hygiene program or used the cohort before this s-OSCE was a part of the curriculum as our control group (6,9,15,25,27–30,41). A testing threat to internal

validity is possible as students became familiar with the testing format and may have memorized the questions asked. However, each s-OSCE had its own case study. This study measured clinical reasoning progression in dental hygiene students during their senior year, however, some progression could have already occurred from their junior to senior year. Students may have gained clinical reasoning from their first semester in clinic during their junior year.

Educators can benefit from the results of this study even though the findings show dental hygiene students' clinical reasoning didn't continuously progress throughout their senior year. Confounding variables such as NBDHE and graduation requirements may have caused poor performance on the s-OSCE from spring to summer. Based on the findings, the dental hygiene program can adjust teaching styles and curriculum to fit their students' needs. Dental hygiene educators need further research to determine the progression of clinical reasoning in senior dental hygiene students over a one-year time frame. Continuation of this study may investigate the effectiveness of teaching strategies that support the development of clinical reasoning skills in the didactic setting and how that knowledge transfers to the clinic setting. Also, research may measure students' clinical reasoning progression from the first semester in clinic to the last rather than senior year specifically.

Conclusion

The purpose of this study was to measure clinical reasoning progression in senior dental hygiene students. However, progression of clinical reasoning did not consistently develop as anticipated. Clinical reasoning progression in the dental hygiene process of

care did improve from fall to spring, but did not improve from spring to summer. The results found in this study were consistent with other research findings that students have not shown clinical reasoning progression over a specific time period chosen by the investigators.

SECTION 4

TABLES

Table I: Alignment of the dental hygiene process of care and clinical reasoning conceptual framework (1,7)

Dental Hygiene Process of Care:					
Step 1: Assessment	Step 2: Dental Hygiene Diagnosis	Step 3: Planning	Step 4: Implementation	Step 5: Evaluation	Step 6: Documentation
Clinical Reasoning Conceptual Framework:					
Step 1: Examine Ask Process	Step 2: Determine	Step 3: Plan	Step 4: Act	Step 5: Evaluate	Step 6: Reflect

Table II: ±Overall ANOVA test comparing all 3 time points.

		Fall	Spring	Summer	P-value±
Assessment	Mean	1.2	1.6	1.9	<.0001
	Std Dev	0.4	0.5	0.3	
	Median	1.0	2.0	2.0	
	Min	1.0	1.0	1.0	
	Max	2.0	2.0	2.0	
DH Diagnosis	Mean	1.4	1.7	1.5	0.2506
	Std Dev	0.6	0.6	0.6	
	Median	1.0	2.0	1.5	
	Min	1.0	1.0	1.0	
	Max	3.0	3.0	3.0	
Treatment Planning	Mean	1.0	1.7	1.3	<.0001
	Std Dev	0.2	0.5	0.5	
	Median	1.0	2.0	1.0	
	Min	1.0	1.0	1.0	
	Max	2.0	2.0	2.0	
Evaluation	Mean	1.4	1.5	1.7	0.1428
	Std Dev	0.5	0.5	0.5	
	Median	1.0	2.0	2.0	
	Min	1.0	1.0	1.0	
	Max	2.0	2.0	2.0	
Clinical Reasoning	Mean	1.0	1.3	1.1	0.0006
	Std Dev	0.0	0.5	0.3	
	Median	1.0	1.0	1.0	
	Min	1.0	1.0	1.0	
	Max	1.0	2.0	2.0	
Total Score	Mean	6.0	7.8	7.4	<.0001
	Std Dev	0.8	1.8	1.2	
	Median	6.0	8.0	7.0	
	Min	5.0	5.0	5.0	
	Max	7.0	11.0	10.0	

N=26 (each student was tested 3 times)
Means (SD) [Median] are presented in the table.

Table III: Assessment

Table of Assessment by time					
Assessment (Assessment)		**time**			
Frequency Col Pct			**Fall**	**Spring**	**Summer**	**Total**
RS	**1**	CT	20	11	3	34
		%	76.92	42.31	11.54	
RS	**2**	CT	6	15	23	44
		%	23.08	57.69	88.46	
Student Total			26	26	26	78

RS=Rubric score, CT= Class total earning rubric score, %= Percent of class

Table IV: Dental Hygiene Diagnosis

Table of DH_Diagnosis by time						
DH_Diagnosis(DH Diagnosis)			time			
Frequency Col Pct			Fall	Spring	Summer	Total
RS	1	CT	17	10	13	40
		%	65.38	38.46	50.00	
RS	2	CT	8	15	12	35
		%	30.77	57.69	46.15	
RS	3	CT	1	1	1	3
		%	3.85	3.85	3.85	
Student Total			26	26	26	78

RS=Rubric score, CT= Class total earning rubric score, %= Percent of class

Table V: Treatment Planning

Table of Treatment_Planning by time					
Treatment_Planning(Treatment Planning)			**time**		
Frequency Col Pct			**Fall**	**Spring**	**Summer**	**Total**
	RS	**1**	CT	25	9	19	53
			%	96.15	34.62	73.08	
	RS	**2**	CT	1	17	7	25
			%	3.85	65.38	26.92	
Student Total				26	26	26	78

RS=Rubric score, CT= Class total earning rubric score, %= Percent of class

Table VI: Evaluation

Table of Evaluation by time					
Evaluation(Evaluation)		**time**			
Frequency **Col Pct**		**Fall**	**Spring**	**Summer**	**Total**
RS	**1**	CT 16 % 61.54	12 46.15	9 34.62	37
RS	**2**	CT 10 % 38.46	14 53.85	17 65.38	41
Student Total		26	26	26	78

RS=Rubric score, CT= Class total earning rubric score, %= Percent of class

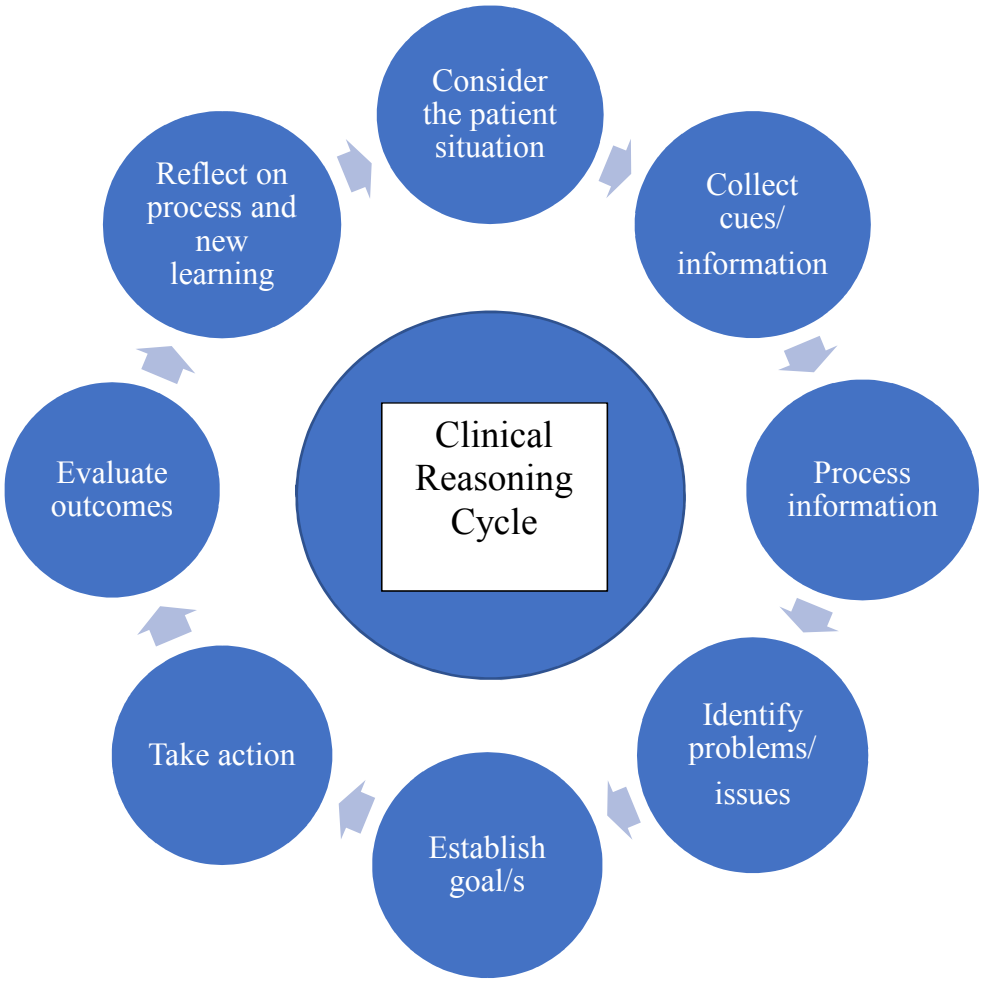
Table VII: Clinical Reasoning

Table of Clinical_Reasoning by time						
Clinical_Reasoning(Clinical Reasoning)			**time**			
Frequency Col Pct			**Fall**	**Spring**	**Summer**	**Total**
	RS	**1**	CT 26 % 100.00	17 65.38	24 92.31	67
	RS	**2**	CT 0 % 0.00	9 34.62	2 7.69	11
Student Total			26	26	26	78

RS=Rubric score, CT= Class total earning rubric score, %= Percent of class

Figures

Figure I: Phases of the clinical reasoning process
The University of Newcastle study phases of clinical reasoning (1)



SECTION 5

Practical Application

Learning and understanding the process of clinical reasoning is crucial to students' education given the importance and implications it has on using evidence-based care. Incorporating clinical reasoning progression into dental hygiene curriculums may reduce the number of errors made by dental hygienists and increase the quality of care given to patients. A dental hygienist provides routine preventive oral health care services to patients. For example, their health care expertise varies greatly between understanding the relationships between diabetes and heart disease in relation to periodontal disease; nutritional counseling and xerostomia in relation to caries prevention; screenings for hypertension and even sleep apnea. All of these medical conditions may be better diagnosed and treated if dental hygienists are using their clinical reasoning skills to give their patients the best care possible.

Dental hygiene educators at the University of Minnesota can use findings from this study to identify the clinical reasoning stagnation that is occurring from spring to summer semesters. Modification to the curriculum can be made to enhance clinical reasoning during those semesters. Not only does practicing clinical reasoning prompt students to start thinking about why and how patient information is relevant, but also instructors may prompt students to recognize the importance of patient information. It is evident that active learning and learning by doing is beneficial to students' education.

SECTION 6

COMPREHENSIVE LIST OF REFERENCES

1. The University of Newcastle, Australian Learning & Teaching, University of Western Sydney. Clinical Reasoning: Instructor Resources. Midwifery. 2009. 1–17 p.
2. Carvalho EC, Oliveira-Kumakura AR d, Morais SCRV. Clinical reasoning in nursing: teaching strategies and assessment tools. Rev Bras Enferm [Internet]. 2017;70(3):662–8. Available from: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0034-71672017000300662&lng=en&tlng=en
3. Benner P, Hughes RG, Sutphen Background M. Patient safety and quality. 1st ed. Rockville, MD: AHRQ; 2008. 87–109 p.
4. Allaire JL. Assessing critical thinking outcomes of dental hygiene students utilizing virtual patient simulation: a mixed methods study. J Dent Educ. 2015;79(9):1082–92.
5. Mccomas MJ, Wright RHA, Mann NKE, Cooper MDE, Jacks ME. M-OSCE as a method to measure dental hygiene students' critical thinking: a pilot study. J Dent Educ. 2013;77(4):485–93.
6. Wetmore AO, Boyd LD, Bowen DM, Pattillo RE. Reflective blogs in clinical education to promote critical thinking in dental hygiene students. J Dent Educ [Internet]. 2010;74(12):1337–1350. Available from: https://www.jdentaled.org/content/74/12/1337.full%5Cnhttp://www.jdentaled.org/content/74/12/1337.full.pdf
7. ADHA. Standards for clinical dental hygiene practice. Access Supl. 2016;1–15.
8. Victor-Chmil J. Critical thinking versus clinical reasoning versus clinical judgment: Differential diagnosis. Nurse Educ. 2013;38(1):34–6.
9. Baron KA. Changing to concept-based curricula: the process for nurse educators. Open Nurs J [Internet]. 2017;11(1):277–87. Available from: http://benthamopen.com/FULLTEXT/TONURSJ-11-277
10. Brussow JA, Roberts K, Scaruto M, Sommer S, Mills C. Concept-based curricula: a national study of critical concepts. Nurse Educ. 2019;44(1):15–9.
11. Jeffries WB, Huggett KN. An introduction to medical teaching: teaching with simulation. Springer. 2010. 79–89 p.
12. Shigli K, Aswini Y, Fulari D, Sankeshwari B, Huddar D, Vikneshan M. Case-based learning: A study to ascertain the effectiveness in enhancing the knowledge among interns of an Indian dental institute. J Indian Prosthodont Soc. 2016;17(1):29–34.
13. Kelly M, Feeley I, Boland F, O'Byrne JM. Undergraduate clinical teaching in rrthopedic surgery: a randomized control trial comparing the effect of case-based teaching and bedside teaching on musculoskeletal osce performance. J Surg Educ [Internet]. 2018;75(1):132–9. Available from: http://dx.doi.org/10.1016/j.jsurg.2017.06.024
14. Sahoo S, Mohammed CA. Fostering critical thinking and collaborative learning

skills among medical students through a research protocol writing activity in the curriculum. Korean J Med Educ [Internet]. 2018;30(2):109–18. Available from: http://www.kjme.kr/journal/view.php?doi=10.3946/kjme.2018.86
15. Carter AG, Creedy DK, Sidebotham M. Critical thinking evaluation in reflective writing: development and testing of carter assessment of critical thinking in midwifery (reflection). Midwifery. 2017;54:73–80.
16. Zhang C, Fan H, Xia J, Guo H, Jiang X, Yan Y. The effects of reflective training on the disposition of critical thinking for nursing students in china: a controlled trial. Asian Nurs Res (Korean Soc Nurs Sci) [Internet]. 2017;11(3):194–200. Available from: https://doi.org/10.1016/j.anr.2017.07.002
17. Mun MS. An analysis of narratives to identify critical thinking contexts in psychiatric clinical practice. Int J Nurs Pract. 2010;16(1):75–80.
18. Ravert P. Patient simulator sessions and critical thinking. Res Briefs. 2008;47(12):557–62.
19. Zarifsanaiey N, Amini M, Saadat F. A comparison of educational strategies for the acquisition of nursing student's performance and critical thinking: simulation-based training vs. integrated training (simulation and critical thinking strategies). BMC Med Educ. 2016;16(294):1–7.
20. Weiner C, Skalen M, Harju-Jeanty D, Heymann R, Rosén A, Fors U, et al. Implementation of a web-based patient simulation program to teach dental students in oral surgery. J Dent Educ. 2016;80(2):133–40.
21. Fida M, Kassab SE. Do medical students’ scores using different assessment instruments predict their scores in clinical reasoning using a computer-based simulation? Adv Med Educ Pract [Internet]. 2015;6:135–41. Available from: http://www.dovepress.com/do-medical-studentsrsquo-scores-using-different-assessment-instruments-peer-reviewed-article-AMEP
22. Oliven A, Nave R, Gilad D, Barch A. Implementation of a web-based interactive virtual patient case simulation as a training and assessment tool for medical students. Stud Health Technol Inform. 2011;169:233–7.
23. Isaza-Restrepo A, Gómez MT, Cifuentes G, Argüello A. The virtual patient as a learning tool: a mixed quantitative qualitative study. BMC Med Educ [Internet]. 2018;18(1):297. Available from: https://bmcmededuc.biomedcentral.com/articles/10.1186/s12909-018-1395-8
24. Al-Madi EM, Celur SL, Nasim M. Effectiveness of PBL methodology in a hybrid dentistry program to enhance students' knowledge and confidence. (a pilot study). BMC Med Educ. 2018;18(1):1–6.
25. Callis AN, McCann AL, Schneiderman ED, Babler WJ, Lacy ES, Hale DS. Application of basic science to clinical problems: traditional vs. hybrid problem-based learning. J Dent Educ [Internet]. 2010;74(10):1113–24. Available from: http://www.ncbi.nlm.nih.gov/pubmed/20930242
26. Whitney EM, Aleksejuniene J, Walton JN. Critical thinking disposition and skills in dental students: development and relationship to academic outcomes. J Dent Educ. 2016;80(8):948–58.
27. Pardamean B. Measuring change in critical thinking skills of dental students

educated in a PBL curriculum. J Dent Educ. 2012;76(4):443–53.
28. Xiao N, Kim G, Zheng M, Baek J, Thor D. Flipped classroom narrows the performance gap between low- and high-performing dental students in physiology. Adv Physiol Educ. 2018;42(4):586–92.
29. Chutinan S, Riedy CA, Park SE. Student performance in a flipped classroom dental anatomy course. Eur J Dent Educ. 2018;22(3):343–9.
30. Gillispie V. Using the flipped classroom to bridge the gap to generation Y. Ochsner J [Internet]. 2016;16(1):32–6. Available from: http://www.ncbi.nlm.nih.gov/pubmed/27046401%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4795497
31. Tune JD, Sturek M, Basile DP. Flipped classroom model improves graduate student performance in cardiovascular, respiratory, and renal physiology. Adv Physiol Educ. 2013;37(4):316–20.
32. Partido B, Soto I. Association between critical thinking and academic performance in dental hygiene students. J Dent Educ. 2019;83(1):32–28.
33. Ali K, Zahra D, Tredwin C, Mcilwaine C, Jones G. Use of progress testing in a UK dental therapy and dental hygiene educational program.pdf. J Dent Educ. 2018;82(2):130–6.
34. Chisnall B, Vince T, Hall S, Tribe R. Evaluation of outcomes of a formative objective structured clinical examination for second-year UK medical students. Int J Med Educ. 2015;6:76–83.
35. Gee BM, Thompson K, Strickland J, Miller LJ. The development of a measurement tool evaluating knowledge related to sensory processing among graduate occupational therapy students: a process description. Occup Ther Int [Internet]. 2017;1–7. Available from: http://dx.doi.org/10.1155/2017/6713012
36. Alrahlah A. How effective the problem-based learning (PBL) in dental education. A critical review. Saudi Dent J [Internet]. 2016;28(4):155–61. Available from: http://dx.doi.org/10.1016/j.sdentj.2016.08.003
37. DeRuisseau LR. The flipped classroom allows for more class time devoted to critical thinking. Adv Physiol Educ. 2016;40(4):522–8.
38. Bohaty BS, Redford GJ, Gadbury-Amyot CC. Flipping the classroom: assessment of strategies to promote student-centered, self-directed learning in a dental school course in pediatric dentistry. J Dent Educ [Internet]. 2016;80(11):1319–27. Available from: http://www.ncbi.nlm.nih.gov/pubmed/27803204
39. Park SE, Howell TH. Implementation of a flipped classroom educational model in a predoctoral dental course. J Dent Educ [Internet]. 2015;79(5):563–70. Available from: http://www.ncbi.nlm.nih.gov/pubmed/25941150
40. Jensen JL, Kummer TA, Godoy PDM. Improvements from a flipped classroom may simply be the fruits of active learning. Life Sci Educ. 2015;14:1–12.
41. Pierce R, Fox J. Vodcasts and active-lelarning exercises in a “flipped classroom” model of a renal pharmacotherapy module. Am J Pharm Educ. 2012;76(10):1–5.
42. Partners H. Code of conduct code of conduct. :1–57.
43. Partners H. Dental Decision Simulation [Internet]. [cited 2017 Oct 16]. Available from: http://hprfstudies.org/DDSimulationUTEval/

44. Linn A, Khaw C. Clinical reasoning: A guide to improving teaching and practice. Aust Fam Physician [Internet]. 2012;41(1):18–20. Available from: http://search.informit.com.au/documentSummary;dn=875577247352301;res=IELHEA
45. Dhaliwal G. Developing teachers of clinical reasoning. Clin Teach. 2013;10(5):313–7.
46. Reed DA, Shanafelt TD, Satele DW, Power D V., Eacker A, Harper W, et al. Relationship of pass/fail grading and curriculum structure with well-being among preclinical medical students: A multi-institutional study. Acad Med. 2011;86(11):1367–73.
47. White CB, Fantone JC. Pass-fail grading: laying the foundation for self-regulated learning. Adv Heal Sci Educ. 2010;15(4):469–77.
48. Yousuf N, Violato C, Zuberi RW. Standard setting methods for pass/fail decisions on high-stakes objective structured clinical examinations: a validity study. Teach Learn Med. 2015;27(3):280–91.
49. Owen MI, Garbett M, Coburn C V., Amar AF. Implementation of deliberate practice as a simulation strategy in nursing education. Nurse Educ [Internet]. 2017;42(6):273–4. Available from: http://insights.ovid.com/crossref?an=00006223-900000000-99748
50. Victor-Chmil J, Turk M, Adamson K, Larew C. Effects of an experiential learning simulation design on clinical nursing judgment development. Nurse Educ. 2015;40(5):228–32.

SECTION 7

APPENDICES

APPENDIX A: IRB RESPONSE

APPROVAL OF NEW STUDY

June 8, 2018

Cyndee Stull

651-324-9099

stul0045@umn.edu

Type of Review:	Initial Study
Title of Study:	Measuring Clinical Reasoning Through the Use of s-OSCEs
Investigator:	Cyndee Stull
IRB ID:	STUDY00003310
Sponsored Funding:	None
Grant ID/Con Number:	None
Internal UMN Funding:	None
Fund Management Outside University:	None
IND, IDE, or HDE:	None
Documents Reviewed with this Submission:	• IRB SOCIAL PROTOCOL.docx, Category: IRB Protocol; • consent form.pdf, Category: Consent Form;

APPENDIX B: COVER LETTER

(Date)

Dear University of Minnesota Dental Hygiene Student,

As a dental hygiene student at the University of Minnesota School of Dentistry, the s-OSCE is a graded component of a clinical course required in each semester of the dental hygiene curriculum. As dental hygienists, it is important that we not only use critical thinking skills, but use clinical reasoning when making evidence-based decisions. Critical thinking takes current knowledge and makes a decision whereas clinical reasoning is a processes of collecting data, processing it, understanding the data and then drawing conclusions in regards to a patient. Clinical reasoning evaluates all the information given and deciphers what is important and what is not. Clinical reasoning is a process that every dental hygiene student completes, but dental hygiene educators are looking for the best method in measuring this process.

The s-OSCE is one of the tools dental hygiene educators can use to identify how dental hygiene students' progress in their clinical reasoning. Therefore, the purpose of this study is to measure the progression of clinical reasoning skills in senior dental hygiene students with the use of s-OSCEs. The study findings will provide data to inform the development of dental hygiene curriculum to foster clinical reasoning skills.

The research team is asking you to be a part of this study by using your results from the required s-OSCE to provide data used in this study. This study will *NOT* affect the grade you receive for this exam. There is *NO* compensation or benefits to you for this study. Your confidentiality will be kept. All information used will be unidentifiable and will *NOT* contain any personal information. While you are required to take the s-OSCE for DH 4226, you are free to withdraw from the study at any time with *NO* consequences to you.

Sincerely,

Shannon Borowicz, MSDH candidate
Cyndee Stull, BSDH, MDH

APPENDIX C: CONSENT FORM

Measuring Clinical Reasoning in Senior Dental Hygiene Students Through the Use of s-OSCEs

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You have been selected to participate in a research study measuring clinical reasoning in senior dental hygiene students tested through s-OSCEs. The s-OSCE is a graded component of a clinical course required in each semester of the dental hygiene curriculum at the University of Minnesota School of Dentistry Division of Dental Hygiene. If you consent, the results from your required s-OSCE will be used as data in this research study. You have been selected for this study because you are currently enrolled as a dental hygiene student at the University of Minnesota School of Dentistry. Before agreeing to participate, it is important that you read and understand the following explanation of the proposed study. After reading the consent form, please ask the researchers to further explain any information or details that you have questions about.

Investigators and Contact Information:

The researchers conducting this study are:

Cynthia Stull, BSDH, MDH
Clinical Assistant Professor
Phone: 612-626-3412
Email: stul0045@umn.edu

Shannon Borowicz BSDH
MSDH student (student investigator)
Phone: 218-478-4529
Email: borow059@umn.edu

Please contact either one with any questions regarding this study.

It is primarily funded by the School of Dentistry Primary Care Department

Study Purpose:

The purpose of this study is to measure the progression of clinical reasoning skills in senior dental hygiene students with the use of s-OSCEs. The study findings will provide data on the development of clinical reasoning among dental hygiene students and inform dental hygiene curricular development.

Study Procedures:

If you agree to participate in this study, we ask you to allow the MSDH student investigator to use your test results from the required s-OSCE from the following dates: October 16th, 2017; February 20th, 2018; and June 28th, 2018 for the use of this study.

Risks of Study Participation

This is a minimal risk study. The study will not ask you to perform or participate in any activities that will cause harm to you or others around you. You will not be asked to do anything that is not

already expected from you as a dental hygiene student in this course. This study will not affect the grade you receive for the s-OSCE.

Benefits of the Study Participation

There are no benefits of participating in this study.

Study Compensation

There is no compensation for participating in this study.

Confidentiality

The data from this research will be stored using Box security online data storage system. All information will be unidentifiable and will *NOT* contain any personal information.

Voluntary Nature of the Study

Participation in this study is voluntary. Your decision whether or not to participate in this study will not affect your current of future relations with the University or the School of Dentistry. If you decide to participate, you are free to withdraw at any time.

Contacts and Questions

To share feedback privately about your research experience, including any concerns about the study, call the Research Participants Advocate Line: 612-625-1650 or give feedback online at www.irb.umn.edu/report.html. You may also contact the Human Research Protection Program in writing at D528 Mayo, 420 Delaware St. Southeast, Minneapolis, Minnesota 55455.

You are encouraged to ask any questions you may have now or at anytime during the study.

Statement of Consent

I have read, reviewed and understand the above information. I have asked questions and have received answers. By signing, I authorize and consent to my participation in the study.

_____ _____

Signature of Participant Date

_____ _____

Signature of Investigator Date

APPENDIX D: s-OSCE RUBRIC

Criteria	**1 point:** ***Does most or many of the following:***	**2 points:** ***Does most or many of the following:***	**3 points:** ***Consistently does all or almost all of the following:***
Assessment	*Fails to identify, analyze, interpret important assessment information related to the case. *Fails to justify rationale for clinical reasoning and decisions made. *Complete and holistic review of case assessment findings is not accomplished.	*Analyze and interpret assessment data within the case. *Interprets evidence and generally justifies rationale for clinical reasoning and decisions made. *Performs a partial review of case assessment findings and applies that to treatment planning of patient care.	*Analyze and interpret assessment data within the case. *Accurately interprets evidence and justifies rationale for clinical reasoning and decisions made. *Performs a complete and holistic review of case assessment findings and applies that to treatment planning of patient care.
DH diagnosis	*Fail to interpret evidence so that appropriate DH diagnoses can be made. *Fails to provide rationale for diagnoses. *Fails to provide needed consultations/approvals.	*Accurately interprets evidence to justify appropriate DH diagnoses; provides thorough rationale for diagnosis. *Identify needed consultations/approvals based on dental hygiene diagnoses and thorough rationale.	*Accurately interprets evidence to justify appropriate DH diagnoses; provides thorough rationale for diagnosis. *Identify needed consultations/approvals based on dental hygiene diagnoses and thorough rationale.
Treatment Planning	*Fails to determine patient needs that can be addressed through dental hygiene care. *Fails to create a dental hygiene treatment plan that reflects patient needs, the DH diagnoses, and needed dental hygiene interventions.	*Determine patient needs that can be improved through the delivery of dental hygiene care. *Create a dental hygiene treatment plan that reflects patient needs, the DH diagnoses, and needed dental hygiene	*Determine patient needs that can be improved through the delivery of dental hygiene care. *Create a dental hygiene treatment plan that reflects patient needs, the DH diagnoses, and needed dental hygiene

	*Fails to justify decisions with thoughtful reflection and rationale. *Fails to identify a plan for continuing care or maintenance.	interventions. This includes preventive services, treatment and consultations. *Justify decisions with thoughtful reflection and rationale. *Identify a plan for continuing care or maintenance.	interventions. This includes preventive services, treatment and consultations. *Justify decisions with thoughtful reflection and rationale. *Identify a plan for continuing care or maintenance.
Evaluation	*Fails to self assess effectiveness of the treatment plan based on lack of appropriate decision-making, use of assessment data, use of rationale and critical thinking.	*Self assess the effectiveness of the case treatment plan based on case findings, own rationale and critical thinking. *Evaluates treatment plan through completion of self-evaluation form.	*Self assess the effectiveness of the case treatment plan based on case findings, own rationale and critical thinking. *Evaluates treatment plan through completion of self-evaluation form.
Clinical Reasoning	*Fails to draw warranted and valid conclusions about patient care based on assessment data. *Fails to justify procedures and provide logical/appropriate rationale for clinical reasoning and decisions made throughout the case. Fails to offer analysis and rationale for alternative treatment options as appropriate to the case.	*Draws warranted and valid conclusions about patient care based on assessment data. *Justifies procedures and provides logical/appropriate rationale for clinical reasoning and decisions made throughout the case. *Offers analysis and rational for alternative treatment options as appropriate to the case.	*Draws warranted and valid conclusions about patient care based on assessment data. *Justifies procedures and provides logical/appropriate rationale for clinical reasoning and decisions made throughout the case. *Offers analysis and rational for alternative treatment options as appropriate to the case.

APPENDIX E: HEALTH PARTNERS CONTRACT

LICENSE AGREEMENT

This License Agreement (**"Agreement"**) is made effective June 18, 2018 (**"Effective Date"**) between HealthPartners Institute (**"Institute"**), a Minnesota nonprofit corporation, with its principal place of business located at 3311 East Old Shakopee Road, Bloomington, Minnesota 55425, and Shannon Borowicz ("Borowicz"), 13367 Wyola Rd Minnetonka, MN 55305, a graduate student enrolled in the Master of Science in Dental Hygiene program (the **"Program"**) at the University of Minnesota School of Dentistry.

RECITALS

A. Institute has developed a proprietary personalized and prioritized, point-of-care clinical decision support tool that includes a proprietary evidenced-based treatment algorithms, provider-oriented and patient-oriented EMR-based or EDR-based interfaces, treatment and safety protocols, case studies (**"Existing Case Studies"**), software, data, content, design, text, graphics, and related instructions, manuals, user guides and other materials (collectively the **"Tool"**), all of which is used to identify risk factors in patients with certain health conditions, to prioritize the risk factors according to what is likely of most to least benefit to the individual patient, and prioritizes clinical treatment recommendations for the provider and patient using interfaces designed to illicit patient preference and improve the efficiency of important decision making.

B. Institute and The Regents of the University of Minnesota (**"University"**), through the University's School of Dentistry (the **"Dental School"**), entered into a License Agreement dated on the Effective Date (the **"University Agreement"**) whereby Institute granted University a license to have access to and use of the dental version of the Tool called Dental Decision Simulation (**"DDSim"**) to train dental hygiene students enrolled in the Dental School (each a **"Student"** and collectively **"Students"**).

C Borowicz desires for the Institute to allow Borowicz, as part of her masters project for her graduate course of study in the Program at University, to modify some Existing Case Studies (**"Modified Case Studies"**) and/or design new Case Studies (**"New Case Studies"**) for University to use in conjunction with DDSim for the University's training of Students as part of the Students' Dental School course curriculum. Existing Case Studies, Modified Case Studies and New Case Studies are hereinafter collectively referred to as **"Case Studies**".

D. Institute is willing to allow Borowicz within the protection of a confidential relationship to create Modified Case Studies and/or New Case Studies for University to use in conjunction with DDSim for the University's training of Students and for such other purposes authorized under this Agreement, in accordance with the terms and conditions of this Agreement.

E. NOW, THEREFORE, in consideration of the foregoing and the mutual covenants hereinafter set forth, the parties hereby agree as follows:

ARTICLE 1 – License

Grant

1.1 Subject to the terms of this Agreement, Institute hereby grants and Borowicz hereby accepts, a non-exclusive, non-transferable, revocable, limited license, without right of sublicense, for Borowicz to create Modified Case Studies and/or New Case Studies for University to use in conjunction with DDSim for the University's training of Students as part of the Students' Dental School course curriculum (the **"Authorized Purpose"**).

1.2 Restrictions; Prohibited Use. Borowicz shall not cause or permit others to: (a) use, access, modify, alter, revise, paraphrase, reproduce, distribute, publish, publicly display, publicly perform, create derivative works of Case Studies, or (b) sublicense, transmit, sell, rent, lease or otherwise transfer Case Studies. In addition, Borowicz shall not, and shall not cause or permit others to modify in any way, or delete, any warnings, notices, liability limitations, or other such provisions contained in Existing Case Studies. ANY UNAUTHORIZED OR UNAPPROVED USE OF CASE STUDIES CONSTITUTES COPYRIGHT AND/OR PATENT INFRINGEMENT AND SUBJECTS BOROWICZ TO ALL CIVIL AND CRIMINAL PENALTIES PROVIDED FOR UNDER COPYRIGHT, PATENT AND OTHER APPLICABLE LAWS AND REGULATIONS. Borowicz shall not, and shall not cause or permit others to, use Case Studies for any purpose that is in violation of (i) this Agreement, (ii) any Institute policies applicable to the subject matter hereof, or (iii) applicable federal or state laws or regulations. Borowicz further acknowledges and agrees that Institute shall have the right to suspend or terminate Borowicz' license granted hereunder if Institute believes, in its sole and reasonable discretion, that Borowicz is in violation of this Agreement or has used or allowed any third party to use Case Studies for any purpose other than the Authorized Purpose.

1.3 Proprietary Rights. Pursuant to this Agreement, Borowicz acquires only the right to use Case Studies for the Authorized Purpose, and acquires no rights of ownership whatsoever in any of the Case Studies. All right, title and interest in and to Case Studies, and any component thereof, unless expressly provided otherwise herein, is and shall remain the exclusive property of Institute. All rights not specifically granted to Borowicz herein are expressly reserved by Institute.

1.4 Institute's Use of Case Studies. The parties agree that Institute may use, reproduce, modify, adapt, translate, publish, publicly display, publicly perform, and create derivative works of, Case Studies for Institute's internal and commercial purposes.

1.5 Borowicz Feedback. Borowicz shall reasonably cooperate with Institute in providing any comments and other feedback with respect to Borowicz' use of Case Studies under this Agreement and any component thereof, including comments and feedback with respect to the effectiveness of Case Studies with respect to the Authorized Purpose.

ARTICLE 2 -Publication

2.1 Definitions. **"Borowicz Publication"** means a thesis written regarding the Case Studies. **"Institute Publication"** means any abstract, article, manuscript, presentation and other forms of publication regarding the Case Studies.

2.2 Publication Rights.

2.2.1 Borowicz' Publication Rights. Borowicz may publish and present a Borowicz Publication to meet academic requirements for graduation from the Program. Borowicz must provide Institute with a copy of the Borowicz Publication for review and comment at least thirty (30) days prior to publishing or presenting the Borowicz Publication. Institute will limit its review to (a) a determination of whether Institute Confidential Information is contained or disclosed in the proposed Borowicz Publication, and will not censor or in any way interfere with presentation or conclusions beyond the extent necessary to protect Institution Confidential Information, and (b) allow Institute to protect its rights in any patentable or copyrightable materials contained in the Borowicz Publication. When requested by Institute, Borowicz will delay publication and presentation of the proposed Borowicz Publication for up to 30 days (**"Review Period"**) to allow Institute to protect its rights it may have in any patentable or copyrightable material contained in the Borowicz Publication. In addition, if notified by Institute within the Review Period, that such Borowicz Publication contains Institute Confidential Information, Borowicz will delete what is reasonably identified as Institute Confidential Information from the Borowicz Publication prior to publication or presentation.

2.2.2 Institute's Publication Rights. Institute reserves the right to publish abstracts, articles, manuscripts, and to give presentation and other forms of publication or presentation of Institute Publications.

ARTICLE 3 - Confidentiality

Borowicz shall not, during the Term (as defined below) or thereafter, divulge, furnish, or make accessible to anyone or use for any purpose other than the Authorized Purpose, any Institute Confidential Information (defined below) which Borowicz has acquired, will acquire, has become acquainted with, or will become acquainted with during the Term or thereafter. **"Institute Confidential Information"** means any information or compilation of information that is confidential and/or proprietary to Institute or derives independent economic value from not being generally known or readily ascertainable by proper means of business, including, but not limited to, Case Studies, DDSim, algorithms, interfaces, guidelines, protocols, software, data, content, designs, text, graphics, instructions, manuals, user guides; financial information; business plans, methods and information of Institute; product research and development; and the terms of this Agreement. Borowicz shall use at least reasonable and prudent care to safeguard and protect and prevent the unauthorized use and disclosure of Institute Confidential Information. If disclosure is ordered by a court or administrative order, Borowicz shall immediately notify Institute.

ARTICLE 4 - Disclaimer; Acknowledgment; Limitation of Liability

4.1 Disclaimer of Warranties. EXISTING CASE STUDIES ARE PROVIDED TO BOROWICZ UNDER THIS AGREEMENT ON AN "AS IS, WITH ALL FAULTS" BASIS, AND BOROWICZ USE THEREOF IS AT BOROWICZ OWN RISK. INSTITUTE MAKES NO WARRANTIES OF ANY KIND WITH RESPECT TO EXISTING CASE STUDIES, EITHER EXPRESS OR

IMPLIED, INCLUDING, WITHOUT LIMITATION, THE IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, TITLE, NON-INFRINGEMENT, OR WARRANTIES ARISING BY COURSE OF DEALING OR CUSTOM OF TRADE. INSTITUTE MAKES NO REPRESENTATION OR WARRANTY THAT ANY CONTENT CONTAINED IN EXISING CASE STUDIES IS ACCURATE, COMPLETE, APPROPRIATE, RELIABLE, OR TIMELY. BOROWICZ IS RESPONSIBLE FOR TAKING ALL PRECAUTIONS IT BELIEVES IS NECESSARY OR ADVISABLE TO PROTECT HER AGAINST ANY CLAIM, DAMAGE, LOSS OR HAZARD THAT MAY ARISE BY VIRTUE OF HER USE OF EXISTING CASE STUDIES.

4.2 Limitation of Liability. UNDER NO CIRCUMSTANCES WHATSOEVER WILL INSTITUTE, OR ANY OF ITS DIRECTORS, OFFICERS, EMPLOYEES, OR AGENTS, BE RESPONSIBLE OR LIABLE TO BOROWICZ OR ANY OTHER INDIVIDUAL OR ENTITY FOR ANY INDIRECT, INCIDENTAL, CONSEQUENTIAL (INCLUDING LOST PROFITS AND LOST BUSINESS OPPORTUNITIES), SPECIAL, EXEMPLARY, OR PUNITIVE DAMAGES, INCLUDING, WITHOUT LIMITATION, DAMAGES THAT RESULT FROM OR RELATE IN ANY MANNER WHATSOEVER TO (A) BOROWICZ USE OF EXISTING CASE STUDIES OR ANY COMPONENT THEREOF, OR RELIANCE ON EXISTING CASE STUDIES BY BOROWICZ, OR (B) ERRORS, INACCURACIES, OMISSIONS, DEFECTS, UNTIMELINESS, SECURITY BREACHES, OR ANY OTHER FAILURE OF EXISTING CASE STUDIES OR FAILURE OF INSTITUTE TO PERFORM. INSTITUTE SHALL NOT BE LIABLE FOR ANY LOSS OR DAMAGE ARISING OUT OF OR RELATING TO ACTS OR OMISSIONS OF INSTITUTE OR RELATING TO BOROWICZ ACCESS TO AND USE OF EXISTING CASE STUDIES HEREUNDER. THE FOREGOING EXCLUSION SHALL APPLY REGARDLESS OF WHETHER INSTITUTE HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. BOROWICZ AND INSTITUTE AGREE THAT THE FOREGOING LIMITATION OF LIABILITY IS AN AGREED ALLOCATION OF RISK BETWEEN THE PARTIES, AND THAT, ABSENT SUCH LIMITATION, INSTITUTE COULD NOT PROVIDE EXISTING CASE STUIDIES TO UNIVERSITY.

ARTICLE 5 -Indemnification

Borowicz shall indemnify and hold harmless Institute and its directors, officers, employees and agents from and against any losses, expenses, costs or damages (including reasonable attorneys' fees and other costs of litigation) finally awarded against Institute by a court of competent jurisdiction or agreed to in a written settlement agreement arising from, incurred as a result of, or in any manner related to (a) Borowicz' breach of the terms of this Agreement, (b) use of Case Studies by Borowicz or University, and (c) the unauthorized or unlawful use of Case Studies by Borowicz or University; provided, however, that: (i) Institute notifies Borowicz promptly in writing of any notice of any such claim, (ii) Institute cooperates with Borowicz in all reasonable respects in connection with the investigation and defense of any such claim, and (iii) Borowicz has sole control of the defense and settlement of any action on any such claim and all negotiations for its settlement or compromise.

ARTICLE 6 - Term and Termination

This Agreement shall be effective on the Effective Date and remain in effect for 2 years (the **"Term"**). The Term may be extended only upon the written agreement of the parties. This Agreement and Borowicz' right to use Case Studies will immediately terminate without further notice at the end of the Term or upon Borowicz' breach of this Agreement. Upon the expiration or termination of this Agreement, Borowicz shall promptly return to Institute or destroy all Institute Confidential Information and all other information which contains, embodies or discloses, in whole or in part Institute Confidential Information, that is in Borowicz' possession or under her control.

ARTICLE 7 - Miscellaneous Provisions

This Agreement constitutes the entire agreement between the parties regarding the subject matter hereof. The parties shall not be bound by or liable for any statement, writing, representation, promise, inducement or understanding not set forth in this Agreement. This Agreement may be executed by any form of signature allowed by law and in counterparts. This Agreement may not be amended except by a written instrument signed by the parties hereto. This Agreement shall be binding upon and inure to the benefit of the parties hereto and their successors and assigns only. Borowicz may not assign this Agreement to any person or entity without the prior written consent of Institute. The parties are independent contractor and nothing in this Agreement shall be construed to create any partnership, joint venture, or employee- employer relationship. Each party's respective obligations under this Agreement which are not, by the expressed terms of this Agreement, fully to be performed during the Term shall survive the termination of this Agreement for any reason. This Agreement shall be construed in accordance with the plain meaning of its terms, and no presumption or inference shall be made against a party responsible for drafting any provision. Any notice or other communication provided for by this Agreement must be in writing and will be deemed given or delivered when personally delivered or when deposited in the United States mail, certified or registered, return receipt requested, postage prepaid and properly addressed, or by recognized overnight courier, next day delivery, charges prepaid, or if given by facsimile, upon evidence of transmission of facsimile, followed by registered or certified mail, addressed to the intended recipients as follows:

INSTITUTE:
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HEALTHPARTNERS INSTITUTE
By: Beverly Prawalsky
Its: Director of Finance
Date: 7/28/2018

SHANNON BOROWICZ
By: Shannon Borowicz
Its: MSDH Candidate
Date: 7/28/2018